

# Association between Childhood Acute Lymphoblastic Leukemia and Use of Electrical Appliances during Pregnancy and Childhood

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As part of a comprehensive study of residential magnetic field exposure in nine midwestern and mid-Atlantic states, we evaluated the use of appliances by 640 patients with acute lymphoblastic leukemia, 0–14 years of age, diagnosed between 1989 and 1993, and 640 matched control children. Mothers were interviewed regarding use of electrical appliances during their pregnancy with the subject and the child's postnatal use. The risk of acute lymphoblastic leukemia was elevated in children whose mothers reported use of an electric blanket or mattress pad during pregnancy [odds ratio (OR) = 1.59; 95% confidence interval (CI) = 1.11–2.29] but was reduced for use of sewing machines during pregnancy (OR = 0.76; 95% CI = 0.59–0.98). The risk of acute lymphoblastic leukemia was increased with children's use of electric blankets or mattress

pads (OR = 2.75; 95% CI = 1.52–4.98) and three other electrical appliances (hair dryers, video machines in arcades, and video games connected to a television), but the patterns of risk for duration in years of use and frequency of use were inconsistent for most appliances used by children. Risks rose with increasing number of hours per day children spent watching television, but risks were similar regardless of the usual distance from the television. The inconsistency in the dose-response patterns for many appliances, reporting and selection bias, and the lack of an effect for measured 60 Hertz magnetic fields or wire codes in our companion study must be considered before ascribing these associations to exposures from magnetic fields. (Epidemiology 1998;9:234–245)

**Keywords:** magnetic fields, appliances, leukemia, childhood, case-control study.

Several epidemiologic studies have reported a link between childhood leukemia and various surrogate measures of past residential magnetic field exposures from nearby power lines,<sup>1–4</sup> but none has found persuasive effects for *contemporaneous* magnetic field measurements taken in homes.<sup>2–5</sup> Household electrical appliances can also contribute to magnetic field exposures. The overall

contribution of most electrical appliances to whole-body time-weighted-average exposures is thought to be small, but appliances may determine the strongest fields to which people are exposed in their homes.<sup>6,7</sup> Only two small case-control studies have evaluated appliance use in relation to the risk of childhood leukemia.<sup>3,8</sup> One study of 70 childhood leukemia cases and 206 controls in the Denver area suggested effects for prenatal electric blanket use,<sup>8</sup> and a study of 232 childhood leukemia cases and 232 controls in Los Angeles found associations with children's use of hair dryers and black and white televisions.<sup>3</sup>

As part of a comprehensive study of residential magnetic field exposure and childhood acute lymphoblastic leukemia (ALL),<sup>9</sup> we evaluated pregnancy-related and childhood use of appliances on the basis of mothers' responses to a detailed questionnaire administered in their homes. We focused on appliances that were the most likely to provide the highest sources of magnetic field exposure (based on typical patterns of use or on published field levels) and those found to be associated with risk in previous studies. We also asked about some appliances that produce only minimal magnetic fields to examine whether media reports linking magnetic fields with childhood disease might possibly have influenced

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mothers' reporting of past appliance exposure. We did not attempt to assess exposure from appliances such as dishwashers, washing machines, and refrigerators, because we believed it would be virtually impossible to quantify the amount of time a child spends in close proximity to these appliances.

## Methods

### STUDY POPULATION

Acute lymphoblastic leukemia patients, 0–14 years of age, diagnosed between 1989 and 1993, were enrolled in the study through a network of pediatric oncologists affiliated with the Children's Cancer Group (CCG). Subjects were eligible for the magnetic field component of the study if they lived in Illinois, Indiana, Iowa, Michigan, Minnesota, New Jersey, Ohio, Pennsylvania, or Wisconsin at the time of diagnosis.<sup>10</sup> Controls selected through random digit dialing<sup>11</sup> were individually matched to the cases by age ( $\pm 25\%$ ), the first eight digits of the telephone number, and race. There were three separate phases of recruitment for this study. Initially, 942 eligible cases and 1,232 eligible controls were identified by the CCG, of whom 900 mothers of cases (96%) and 973 mothers of controls (75%) completed a comprehensive telephone interview. Subsequently, we interviewed 832 cases and 801 controls (98% of cases and 97% of controls who had participated in the CCG interview phase and had individual hospital institutional review board approval for the magnetic field exposure assessment) by telephone to obtain a complete lifetime residential history. In-home interviews were completed for 788 cases and 699 controls. Taking into account participation during the initial recruitment of cases and controls by CCG interviewers (96% for cases and 75% for controls), and participation during the residential telephone interview phase (98% for cases and 97% for controls), the final participation rates for the in-person interview were 88% for cases and 64% for controls.

### DATA COLLECTION

We telephoned mothers to obtain the child's lifetime residential history and visited the subject's home to measure magnetic fields and to interview mothers about electrical appliance use and other exposures. As part of the lifetime residential history, we collected data on the home heating source (electric, natural gas, or other), air conditioning, and type of stove (electric vs natural gas) for each home the subject resided in since conception. The in-person computer-aided interview contained questions on mother's use during pregnancy and child's use of electric blankets, mattress pads, heating pads, water beds, stereo or other sound systems, television (including watching videotapes) and video games connected to a television, video machines located in arcades, computers, microwave ovens, sewing machines, hair dryers, curling irons, ceiling fans, humidifiers, night lights, and electric clocks. We included several potential "red herring" appliances (stereo systems without headsets, night lights, and ceiling fans) unlikely to have

substantial magnetic field exposures. We felt any potential recall bias concerning magnetic field exposures might include all electrical appliances, even those without meaningful magnetic fields.

Mothers were asked about frequency of use, number of months used, and trimesters of use of specific appliances during their pregnancy with the subject. We also collected data on the child's use of appliances before the reference date, defined as the date of diagnosis for the acute lymphoblastic leukemia patient and its matched control, and the age of the child or the year when he/she started and stopped using the appliance. In a pilot study, many mothers indicated that they could not provide accurate information on frequency of use by their child during earlier years or reported that appliance use did not vary year by year; therefore, we asked about frequency of use only during the year before the reference date for most appliances. For three appliances with potentially high exposure to magnetic fields (electric blankets, water beds, and hair dryers), we collected information on frequency of use during the last year of use if the child had stopped using the appliance before the beginning of the reference year. Limited information was also collected during the initial telephone interview, conducted by CCG interviewers, on mothers' and children's use of electric blankets and water beds.

### STATISTICAL ANALYSIS

There were 651 matched pairs among the 788 cases and 699 controls who were interviewed. We excluded 11 pairs from the analysis because one member of the pair (10 acute lymphoblastic leukemia patients, 1 control) had Down syndrome, which has been linked with an extremely high risk of acute lymphoblastic leukemia.<sup>12</sup>

For each appliance, we attempted to distinguish between occasional and frequent users. For appliances that are generally used for several hours at a time, such as electric blankets and water beds, we collected detailed information on daily length of time subjects were exposed. The "high"-use group was defined as those who reported using an electric blanket daily, for 6 or more hours, for at least 2 months during the year before the reference date. In contrast, for appliances used for relatively short periods of time, such as hair dryers and curling irons, we asked whether these appliances were used daily, at least once per week, or less often, rather than the average number of minutes of use. Because few children used hair dryers or curling irons on a daily basis, we defined the high-use category as use at least weekly for at least 6 months. For television, we asked about the average amount watched each day, usual distance from the television, and characteristics of televisions that might result in variation in exposure level, such as size, age, and black and white or color. Because nearly all children watched television from an early age, we did not assess duration in years of use.

In general, we did not combine information from multiple appliances to create an overall estimate of exposure from appliances, as some authors have advocat-

ed,<sup>13</sup> owing to the wide variations in patterns of use and associated magnetic field exposures produced by different appliances. We did create a variable for cumulative time during the reference year that children spent watching television in close proximity to the appliance and playing with video games connected to televisions, because the exposures at similar distances would presumably be the same. Children whose mothers reported that they usually sat more than 6 feet away did not contribute any time to this variable. Too few mothers reported use of electric mattress pads to evaluate this exposure separately; therefore, we analyzed mattress pads and electric blankets together. Results were similar when we analyzed electric blankets alone or combined with electric mattress pads; therefore, we report results just for the combined variable. We also estimated cumulative lifetime exposure to electric blankets by summing estimates of the number of hours that electric blankets were used during the pregnancy and during the child's lifetime.

We computed odds ratios for each appliance for prenatal and postnatal use separately. We compared ever- vs never-use, and regular ("high") use vs occasional use. We computed duration of use among children based on the difference between the age stopped and started. For pregnancy exposure, we also assessed trimester of use, by comparing any reported use during each trimester with nonusers, for each appliance. We used stratified and conditional logistic regression models to assess the effects of potential confounding or modifying variables.<sup>14</sup> We evaluated trends in risk with increasing years of use and frequency of use of appliances among exposed subjects only by entering these variables ordinally into the models. For several appliances, we also created variables to examine trends in frequency and duration of use simultaneously. For example, the lowest category for children's use of hair dryers consisted of those who reported less than weekly use for less than 1 year, and the highest category were those who reported regular (more than weekly use) for 3 or more years.

We controlled for income and maternal education simultaneously in all logistic regression models because of case-control differences in income and education (Table 1). We also analyzed the data for each appliance, stratifying on total household income, maternal education, parental age, occupation, smoking habits, type of dwelling and urbanization, number of siblings, and whether the child was breast fed. We looked for patterns according to subjects' gender, age, and the immunophenotype of the cases. Because the contribution of appliances to time-weighted-average magnetic field exposure may be more important in residences with low exposure levels,<sup>15,16</sup> we also evaluated risks within five levels of a summary of exposure to residential magnetic fields, based primarily on a 24-hour time-weighted average of magnetic fields taken in the child's bedroom.<sup>9</sup> Because control interviews lagged behind those of cases (Table 1), we stratified the data by the length of time that had elapsed between the reference and interview dates to evaluate the consistency of results across the different

time intervals, and we included this variable in logistic models.

## Results

Over half of the cases (59.4%) and controls (58.5%) were less than 5 years of age at diagnosis/reference date, and subjects were predominantly white (Table 1). Cases had a lower total household family income at diagnosis, and slightly lower maternal educational attainment. Mothers' occupational categories were similarly distributed for cases and controls, but a somewhat larger proportion of case than control fathers reported a blue collar occupation at the reference date. Seventy-four per cent of cases were interviewed within 2 years of diagnosis, in contrast to 48% of controls.

### MOTHERS' USE OF APPLIANCES DURING PREGNANCY

Small excess risks of acute lymphoblastic leukemia were seen among offspring of mothers who reported ever using electric blankets or mattress pads, heating pads, and humidifiers during pregnancy, but there was no trend with increasing risk by frequency of use of electric blankets and heating pads. For humidifiers, only infrequent, nonregular use was associated with an excess risk (Table 2). We observed no important association for time spent watching television during pregnancy, and little indication of an effect for distance from the television. We noted reduced risks among mothers who reported ever using a sewing machine or listening to a stereo system without a headset during the index pregnancy. Acute lymphoblastic leukemia was not associated with use of water beds, hair dryers, curling irons, electric clocks, microwave ovens, ceiling fans, sound systems with headsets, electric stoves, electric heat, or air conditioning during pregnancy.

For most appliances, there was little variation in mothers' reported pattern of use by trimester, and therefore few differences in risk by trimester could be assessed. Exceptions were electric blankets, which tend to be used seasonally, and heating pads, which may be used sporadically for specific problems. We found little association between acute lymphoblastic leukemia and use of an electric blanket during the first trimester (OR = 1.20; 95% CI = 0.72–2.01), whereas use during the second (OR = 1.91; 95% CI = 1.16–3.14) and third (OR = 1.74; 95% CI = 1.05–2.88) trimesters was associated with increased risk compared with nonuse. In contrast, there was a comparatively strong association between reported use of heating pads during the first trimester (OR = 1.93; 95% CI = 1.03–3.63) but not during the second (OR = 1.21; 95% CI = 0.74–2.26) or third trimesters (OR = 1.18; 95% CI = 0.74–1.88).

We compared the responses to the questions on maternal use of electric blankets from the initial CCG telephone interview with results of our in-person interview (Table 3). The consistency of responses was poor; however, there was no marked difference between the proportion of case and control mothers who responded differently during the two interviews. The effect on

TABLE 1. Characteristics of Matched Cases and Controls with Interview Data on Electrical Appliances\*

Characteristics	Cases		Controls	
	Number	%	Number	%
Gender				
Male	333	52.0	337	52.7
Female	307	48.0	303	47.3
Age (years) at diagnosis/reference date				
<2	68	10.6	85	13.3
2-4	312	48.8	289	45.2
5-9	179	28.0	185	28.9
≥10	81	12.7	81	12.7
Race				
White	585	91.4	612	95.6
Black	20	3.1	16	2.5
Other	35	5.5	12	1.9
Income during reference year				
<\$20,000	113	17.7	77	12.0
\$20,000-\$29,999	122	19.1	86	13.4
\$30,000-\$39,999	133	20.8	112	17.5
\$40,000-\$49,999	98	15.3	105	16.4
≥\$50,000	168	26.3	255	39.8
Missing	6	0.9	5	0.8
Mother's education				
< High school	57	8.9	30	4.7
High school	220	34.4	224	35.0
Some college	210	32.8	199	31.1
College graduate	153	23.9	187	29.2
Mother's occupation				
Professional	131	20.5	148	23.1
White collar	156	24.4	172	26.9
Blue collar	45	7.0	29	4.5
Housewife	308	48.1	291	45.5
Father's occupation				
Professional	190	29.7	200	31.3
White collar	103	16.1	119	18.6
Blue collar	285	44.5	240	37.5
Missing	62	9.7	81	12.7
Urbanization				
Urban	169	26.4	136	21.3
Suburban	271	42.3	293	45.8
Rural	200	31.3	210	32.8
Months between reference date and interview				
7-12	86	13.4	3	0.5
13-18	256	40.0	107	16.7
19-24	134	20.9	196	30.6
25-36	129	20.2	238	37.2
≥37	35	5.5	96	15.0

\* Excludes 11 pairs in which one member of the pair had Down syndrome.

acute lymphoblastic leukemia in relation to mothers' use of electric blankets as reported during the initial CCG interview was slightly smaller (OR = 1.43; 95% CI = 0.99-2.05) than that based on the subsequent in-person interview (OR = 1.58; 95% CI = 1.08-2.31). Nevertheless, when we limited the analysis to those who responded consistently in the two interviews, the effect was virtually identical to that calculated from the National Cancer Institute/CCG in-person interview data (OR = 1.59; 95% CI = 1.02-2.47). We also computed acute lymphoblastic leukemia risks in relation to maternal electric blanket use reported in the initial interview, including subjects who subsequently refused to participate in the electromagnetic field component of the

study, and found that the results were virtually unchanged (OR = 1.40; 95% CI = 0.99-1.98), based on 768 matched pairs.

#### CHILDREN'S USE OF APPLIANCES

When we examined any use before the reference date, four appliances (electric blankets, hair dryers, video machines in arcades, and video games connected to a television) were associated with increased risks of childhood acute lymphoblastic leukemia, and two (sound systems with headsets and video machines in arcades) had increasing risks as duration of use rose (Table 4). For electric blankets and hair dryers, there was no clear

TABLE 2. Distribution of Cases and Controls by Use of Appliances during Pregnancy and Odds Ratios<sup>†</sup> and 95% Confidence Intervals from Matched Analyses

	Cases	Controls	OR	95% CI
<i>Bedroom appliances</i>				
Electric blanket/mattress pad				
Never used‡	547	579	1.00	
Ever used	91	61	1.59	1.11-2.29
< Weekly	6	5	1.61	0.46-5.65
<6 hours/day or <2 months	37	27	1.52	0.89-2.60
≥6 hours/day for ≥2 months	47	29	1.63	0.99-2.68
Water bed				
Never used‡	483	476	1.00	
Ever used	157	164	0.90	0.67-1.21
<6 hours/day or <6 months	29	28	0.89	0.51-1.55
≥6 hours/day for ≥6 months	127	136	0.89	0.65-1.23
Heating pad				
Never used‡	555	578	1.00	
Ever used	82	60	1.46	1.00-2.13
< Weekly	40	29	1.44	0.85-2.43
≥ Weekly	42	30	1.52	0.91-2.53
Humidifier				
Never used‡	532	561	1.00	
Ever used	107	79	1.42	1.01-1.98
< Daily or <3 months	65	39	1.86	1.16-2.97
Daily for ≥3 months	42	40	1.06	0.66-1.71
Electric clock				
Never used or not within 3 feet‡	152	139	1.00	
Digital display	424	429	0.98	0.73-1.31
Dial display	61	67	0.81	0.52-1.28
<i>Personal care appliances</i>				
Hair dryer				
Never used‡	81	79	1.00	
Ever used	559	559	1.14	0.80-1.61
< Daily or <6 months	303	322	1.04	0.72-1.51
Daily for ≥6 months	254	236	1.28	0.88-1.87
Curling iron				
Never used‡	230	233	1.00	
Ever used	409	406	1.06	0.83-1.36
< Daily or <6 months	202	192	1.08	0.81-1.43
Daily for ≥6 months	206	213	1.06	0.80-1.42
<i>Kitchen appliances</i>				
Microwave oven				
Never used‡	242	221	1.00	
Ever used	396	419	0.89	0.66-1.21
< Daily	94	109	0.81	0.56-1.19
Once/day	172	187	0.89	0.63-1.25
> Once/day	130	123	1.00	0.69-1.45
Electric stoves§				
No‡	241	232	1.00	
Yes	291	304	0.98	0.74-1.30
Missing	108	104		
<i>Entertainment/other appliances</i>				
Stereo system				
Never used‡	142	124	1.00	
Ever used	498	516	0.81	0.61-1.07
< Daily or <6 months	389	389	0.87	0.65-1.17
Daily for ≥6 months	108	126	0.66	0.45-0.95
Sound system with headset				
Never used‡	573	577	1.00	
Ever used	66	63	0.93	0.63-1.37
< Weekly or <9 months	52	51	0.91	0.59-1.40
≥ Weekly for ≥9 months	14	12	1.00	0.44-2.26
Television				
Time spent watching during index pregnancy				
<2 hours/day‡	101	115	1.00	
≥2 and <4 hours/day	234	256	1.01	0.69-1.49
≥4 and <6 hours/day	155	145	1.17	0.78-1.76
≥6 hours/day	149	122	1.12	0.73-1.72

Table 2—continues

TABLE 2. Continued

	Cases	Controls	OR	95% CI
Distance from television¶				
>6 feet	337	376	1.00	
4-6 feet	274	238	1.20	0.93-1.54
<4 feet	17	12	1.89	0.79-4.50
Sewing machine				
Never used‡	441	397	1.00	
Ever used	198	242	0.76	0.59-0.98
< Weekly or <3 months	151	178	0.79	0.59-1.04
≥ Weekly for ≥3 months	47	64	0.70	0.46-1.05
Personal computer				
Never used‡	463	456	1.00	
Ever used	177	184	1.05	0.79-1.38
<30 minutes/day	39	36	1.17	0.71-1.95
≥30 minutes/day and <4 hours/day	59	78	0.79	0.53-1.18
≥4 hours/day	78	68	1.29	0.88-1.91
Heating and cooling appliances				
Ceiling fan				
Never used‡	481	462	1.00	
Ever used	159	178	0.85	0.64-1.14
< Daily or <3 months	96	123	0.73	0.52-1.03
Daily for ≥3 months	63	55	1.09	0.73-1.65
Electric heat§				
None‡	443	451	1.00	
Secondary source of heat	13	18	0.60	0.26-1.38
Primary source of heat	71	66	1.17	0.79-1.73
Missing	113	105		
Air conditioning§				
None‡	183	170	1.00	
Window only	167	180	0.98	0.69-1.39
Central	182	186	1.37	0.93-2.04
Missing	108	104		

† Adjusted for child's gender, household income at the reference date, and maternal education.

‡ Referent category.

§ Use of electric stoves, air conditioning, and electric heat during pregnancy (in main pregnancy residence); data collected during telephone interview on residential history.

|| Adjusted for distance from television.

¶ Adjusted for time spent watching television.

relation with duration in years of use, since the highest odds ratios were seen for less than 1 year of use. Trend evaluation was not persuasive for video games connected to television and curling irons. These results did not materially change when we examined the effects within three age strata (data not shown). There was no material association between acute lymphoblastic leukemia and

the "red herring" variables, night lights and stereo systems without headsets (Table 4).

We also assessed the association between acute lymphoblastic leukemia and an estimate of the total lifetime hours that the child was exposed to an electric blanket during pregnancy and childhood and found no evidence for dose-response trends. The strongest association was found in the lowest exposure group (OR for <100 hours during their lifetime = 2.15; 95% CI = 1.06-4.36; OR for 100-600 lifetime hours = 1.50; 95% CI = 0.83-2.70; OR for ≥600 lifetime hours = 1.78; 95% CI = 1.03-3.08).

We found little evidence for dose-response trends among the exposed when we examined the results according to children's frequency of use of appliances (data not shown). Four appliances (electric blankets, hair dryers, microwave ovens, and video games connected to televisions) did show an increased risk in the highest use category, but these risks were not substantially different from those that were calculated based on ever- vs never-use of the appliances. There was no important association between acute lymphoblastic leukemia and the highest reported frequency of use for water beds, humid-

TABLE 3. Responses by Case and Control Mothers to Questions about Any Use of Electric Blanket during Index Pregnancy in CCG Telephone and NCI In-Person Interview\*

	Response to CCG Questionnaire					
	Yes			No		
	Response to NCI Questionnaire			Response to NCI Questionnaire		
	Yes	No	% Agreement	Yes	No	% Agreement
Case mothers	74	28	72	21	635	97
Control mothers	44	24	65	14	595	98

\* Excludes 17 cases and 10 controls who answered "Don't know" to first questionnaire.

TABLE 4. Distribution of Cases and Controls by Use of Appliances during Childhood and Odds Ratios<sup>†</sup> and 95% Confidence Intervals from Matched Analyses

	Cases	Controls	OR	95% CI
<i>Bedroom appliances</i>				
Electric blanket/mattress pad				
Never used‡	593	619	1.00	
Ever used	45	19	2.75	1.52-4.98
<1 year	10	3	5.45	1.14-26.06
1-2 years	18	9	2.19	0.95-5.05
≥3 years	17	7	2.63	1.05-6.59
Water bed				
Never used‡	522	539	1.00	
Ever used	118	99	1.19	0.87-1.62
<1 year	23	18	1.22	0.61-2.44
1-2 years	52	44	1.17	0.74-1.84
≥3 years	42	37	1.15	0.70-1.92
Humidifier				
Never used‡	346	349	1.00	
Ever used	294	289	1.04	0.82-1.31
<1 year	40	34	1.20	0.70-2.07
1-2 years	116	115	1.03	0.75-1.43
≥3 years	135	139	0.99	0.72-1.35
Bedside electric clock				
Not used during reference year‡	458	461	1.00	
Digital	95	85	1.20	0.83-1.76
Dial	14	8	1.69	0.61-4.65
Night light				
Never used‡	227	193	1.00	
Ever used	413	445	0.81	0.63-1.04
<1 year	40	25	1.65	0.91-3.01
1-2 years	134	152	0.75	0.54-1.04
≥3 years	234	268	0.77	0.57-1.03
<i>Personal care appliances</i>				
Hair dryer				
Never used‡	374	416	1.00	
Ever used	266	221	1.55	1.18-2.05
<1 year	33	16	2.50	1.28-4.87
1-2 years	127	110	1.41	1.02-1.96
≥3 years	106	95	1.54	1.02-2.30
Curling iron§				
Never used‡	176	183	1.00	
Ever used	93	78	1.74	0.91-3.31
<1 year	21	16	1.50	0.53-4.23
1-2 years	41	39	1.47	0.68-3.15
≥3 years	31	23	3.56	1.05-12.12
<i>Entertainment appliances</i>				
Stereo system				
Never used‡	189	176	1.00	
Ever used	451	462	0.84	0.65-1.08
<1 year	32	31	0.82	0.45-1.49
1-2 years	150	147	0.86	0.61-1.20
≥3 years	269	284	0.83	0.62-1.11
Sound system with headset				
Never used‡	407	412	1.00	
Ever used	164	143	1.34	0.97-1.84
<1 year	44	48	0.94	0.58-1.53
1-2 years	82	76	1.40	0.94-2.09
≥3 years	37	19	3.04	1.48-6.26
Video arcade machine¶				
Never used‡	215	250	1.00	
Ever used	251	213	1.66	1.18-2.33
<1 year	42	51	1.10	0.66-1.82
1-2 years	115	101	1.70	1.14-2.54
≥3 years	92	60	2.78	1.64-4.72
Video games connected to television¶¶				
Never used‡	215	261	1.00	
Ever used	253	203	1.91	1.36-2.68
<1 year	35	39	1.31	0.73-2.35
1-2 years	154	113	2.04	1.40-2.98
≥3 years	64	50	2.36	1.31-4.25

Table 4—continues

TABLE 4. Continued

	Cases	Controls	OR	95% CI
Personal computer				
Never used†‡	384	368	1.00	
Ever used	188	186	1.20	0.83-1.73
<1 year	27	23	1.55	0.80-2.99
1-2 years	100	92	1.17	0.79-1.75
≥3 years	60	70	0.93	0.53-1.66
Kitchen appliances				
Microwave oven				
Never used†‡	198	220	1.00	
Ever used	374	335	1.33	0.99-1.79
<1 year	24	25	0.85	0.43-1.66
1-2 years	152	108	1.59	1.10-2.31
≥3 years	197	201	1.30	0.92-1.83
Electric stove#				
No†‡	293	270	1.00	
Yes	345	365	0.90	0.69-1.16
Heating/cooling appliances				
Air conditioning#				
None†‡	200	185	1.00	
Window only	211	204	1.01	0.74-1.37
Central	226	245	1.08	0.76-1.53
Electric heat#				
None†‡	540	524	1.00	
Secondary source	25	24	1.09	0.60-1.99
Primary source	70	85	0.81	0.57-1.16

† Adjusted for child's gender, household income at the reference date, and maternal education.

‡ Referent category.

§ Females 2 years of age and older at the reference date.

|| Subjects 2 years of age and older at the reference date.

¶ Subjects 3 years of age and older at the reference date.

# Data taken from lifetime residential history, not from interview on electrical appliances.

ifiers, curling irons, stereo systems, sound systems with headsets, video arcade machines, or personal computers.

Risks rose with increasing time spent watching television, and for the combined time spent watching television and playing video games connected to television, but there was no meaningful trend in risk with increasing frequency of playing video games alone (Table 5). Because the amount of time children spend watching television may change with age, and because of the lag in time between interviewing cases and controls, we also controlled for age at interview but found little difference in the results (OR = 2.46 for ≥6 hours per day). There were slightly elevated risks among children sitting within 6 feet of the television compared with those sitting 6 or more feet away, but the odds ratios were similar for those who reported a usual distance of less than 4 feet, and 4-6 feet. There was no clear pattern of increasing risk with decreasing distance when we examined the effects of time spent watching television and distance from the television jointly (Table 6). The few subjects who primarily watched black and white televisions did not have higher risks compared with those who most often watched color televisions (data not shown). In addition, we found little difference in acute lymphoblastic leukemia risk according to the age or size of the television (data not shown).

For most appliances, we found no evidence of confounding or effect modification by subject or family characteristics. We found similar patterns of risk when

the data were stratified by the number of months that had elapsed between the reference date and interview, and adjustment for this variable in logistic models had little effect. There was also no evidence that increases in risk were primarily attributable to use very close in time to the reference date. We found no consistent difference in effect estimates for electric blankets, water beds, televisions, video games, or hair dryers among subjects with different levels of summary measured residential magnetic fields (data not shown). There was also no discernible pattern of differences in risk according to immunophenotype category of the cases, although small numbers in some categories limited the assessment (data not shown).

## Discussion

### INDIVIDUAL APPLIANCES

#### Electric Blankets

Prolonged and relatively high exposure to magnetic fields can result from use of electric blankets.<sup>17,18</sup> In contrast to the median magnetic flux density of 0.065  $\mu$ T measured in homes in our study,<sup>9</sup> the average level of magnetic fields from electric blankets is about 2.2  $\mu$ T, with considerably lower levels for most blankets manufactured after 1989.<sup>19,20</sup> We did not collect data on the year of purchase of the electric blanket. Because only 3% of the mothers who reported using electric blankets gave birth to their index child after 1989 and 14% of children

TABLE 5. Distribution of Cases and Controls by Children's Patterns of Television and Video Game Use during the Reference Year and Odds Ratios<sup>†</sup> and 95% Confidence Intervals from Matched Analyses

Appliance	Cases	Controls	OR	95% CI
Video games connected to television <sup>‡</sup>				
Never used <sup>§</sup>	215	261	1.00	
< Weekly or <10 minutes/day	99	79	1.84	1.22-2.78
10-59 minutes/day	68	57	1.77	1.10-2.82
≥60 minutes/day	75	64	1.87	1.13-3.10
Television				
Time spent watching during reference year <sup>  </sup>				
<2 hours/day <sup>§†</sup>	84	108	1.00	
≥2 and <4 hours/day	202	257	0.98	0.65-1.46
≥4 and <6 hours/day	171	163	1.38	0.89-2.14
≥6 hours/day	178	109	2.39	1.50-3.80
Distance from television <sup>¶</sup>				
>6 feet	90	125	1.00	
≥4 and ≤6 feet	363	348	1.71	1.20-2.44
<4 feet	166	142	1.60	1.08-2.37
Television and video games combined				
<2 hours/day <sup>‡,§</sup>	139	190	1.00	
≥2 and <4 hours/day	172	178	1.43	1.02-1.99
≥4 and <6 hours/day	142	136	1.49	1.03-2.16
≥6 hours/day	172	114	2.31	1.60-3.34

<sup>†</sup> Adjusted for child's gender, household income at the reference date, and maternal education.

<sup>‡</sup> Subjects 3 years of age and older at the reference date.

<sup>§</sup> Referent category.

<sup>||</sup> Adjusted for distance from the television.

<sup>¶</sup> Adjusted for time spent watching television.

# Children who watched television at ≥6 feet included in reference category.

who used electric blankets first used them in 1990 or later, most of the blankets used were likely to have been old-style. The lack of dose-response effects for electric blanket use during pregnancy, childhood, or using an estimate of lifetime exposure implies that the associations found may not reflect magnetic field exposures from electric blankets.

#### Water Beds

As in previous studies, we found no meaningful association between the risk of acute lymphoblastic leukemia and use of electrically heated water beds during either pregnancy or childhood. Water bed heaters produce lower magnetic fields than electric blankets but are used throughout the year; however, the strength of magnetic fields from water beds depends upon the position of the heater.<sup>18</sup>

#### Hair Dryers and Curling Irons

Magnetic fields from hair dryers can range between 0.100 and 70.0  $\mu$ T within 6 inches of the electric motor.<sup>20</sup> Childhood use of hair dryers at least weekly was associated with an increased risk of childhood leukemia in one<sup>3</sup> of two<sup>3,8</sup> earlier reports. In our data, there was also an increased risk with postnatal use of hair dryers, but no evidence of dose-response relation, with the largest effect observed in children who had used them for less than 1 year.

Curling irons contain only a heating element but no motor and therefore may produce magnetic fields considerably lower than those of hair dryers, a conclusion supported by a limited number of measurements.<sup>7</sup> We found no evidence of increasing risk with increasing frequency of use during the reference year (data not

TABLE 6. Association of Childhood Acute Lymphoblastic Leukemia and Reported Time Spent Watching Television and Distance from the Television by the Child during the Reference Year<sup>\*,†</sup>

Time Watched (Hours)	Distance from Television (feet)					
	≥6		4-6		<4	
	OR	95% CI	OR	95% CI	OR	95% CI
<2	1.00 <sup>‡</sup>		1.49	0.62-3.56	2.13	0.69-6.60
2 to ≤4	0.59	0.25-1.43	2.14	0.96-4.75	1.33	0.57-3.10
4 to ≤6	1.92	0.72-5.07	2.23	0.96-5.17	2.31	0.94-5.69
≥6	4.67	1.64-13.36	3.40	1.47-7.89	4.39	1.75-11.04

\* Odds ratios and 95% confidence intervals, from matched analysis.

<sup>†</sup> Adjusted for income, maternal education, and gender.

<sup>‡</sup> Referent category, based on 14 cases and 22 controls.

shown), and there also was no clear-cut trend for duration in years of use within exposed subjects.

*Televisions, Video Games Connected to Televisions, Video Games in Arcades, and Personal Computers*

Magnetic fields can range up to 2.0  $\mu\text{T}$  very near the television, but levels beyond 3–4 feet are generally indistinguishable from background magnetic field levels.<sup>20</sup> Color televisions tend to have higher magnetic fields than those from black and white units.<sup>21</sup> Viewing black and white, but not color, television was associated with an elevated risk of childhood leukemia in the Los Angeles study; however, no detail was provided on risks according to the amount of time watched or the usual distance between the child and the television.<sup>3</sup> Televisions were not evaluated in the Denver study.<sup>8</sup>

The associations we found for time children spent watching television, as well as for use of video games connected to televisions, combined television and video game use, and video machine use in arcades were present across age and sex categories. The effect that we observed for number of hours of television watched per day was similar regardless of the distance from the television, implying that magnetic fields are unlikely to be a causal factor.

No published data on magnetic field levels from video arcade machines is available. Two studies that measured magnetic fields at a distance of 50 cm (20 inches) from seven video display terminals found an average field of 0.08  $\mu\text{T}$ .<sup>22,23</sup> Previous studies of childhood leukemia have not examined risks associated with the use of computers.<sup>3,8</sup> Computer use was rare in our study (8% of controls reported 30 or more minutes of computer use per day) and was not associated with acute lymphoblastic leukemia.

*Other Appliances*

The small increase in risk for children's use of microwave ovens, which have measurable 60-Hertz fields at a distance of several feet,<sup>7</sup> was not accompanied by a dose-response pattern with increasing number of years used. A true effect of microwave ovens would be consistent with a peak-exposure rather than time-weighted-average effect, because children are not likely to stand next to an operating microwave oven for long periods. Although the use of stereo or sound systems with headphones was associated with increased risk of acute lymphoblastic leukemia, and there seemed to be a dose-response effect for increasing years of use, we observed a higher risk for intermittent use during the reference year than for regular use. The reduced risk associated with the use of sewing machines during pregnancy is also inconsistent with a causal effect of magnetic fields, since sewing machines have rather high magnetic field levels,<sup>20</sup> and the user's abdomen would usually be quite close to the motor.

INTERPRETATION OF FINDINGS

Interpretation of the interview data on appliance use should take into account findings from the magnetic field measurement and wire coding components of the

study.<sup>9</sup> We found little evidence for an association between measured summary time-weighted-average exposure to power frequency magnetic fields or wire codes and an increased risk of acute lymphoblastic leukemia.<sup>9</sup> Our study is the largest to date, covered a nine-state geographic area, had the same eligibility requirements for cases and controls, and took measurements closer in time to diagnosis than in previous studies. Assessment for the power line component of the study, although retrospective, was based on measurements of magnetic fields and wire coding of homes that children resided in for a large proportion of their lifetime, whereas assessment of appliance exposures was derived solely from retrospective interviews. For all appliances, exposure drops precipitously with distance and usually affects only part of the body. In contrast, exposure from residential power lines is continuous, daily, and nearly uniform to the whole body.

Our effort to obtain appliance exposure, although more extensive than in past studies, was still far from complete. No measurement was taken of magnetic fields associated with the actual appliances used, although there are substantial variations in magnetic fields among appliances of the same type.<sup>20,23</sup> We did not collect detailed lifetime histories of use or information on the subject's distance from the appliance (except for television watching). We also did not distinguish between radiant electric heat, which may be associated with relatively high magnetic fields, and other sources of electric heat. Different appliances can give evidence about different metrics; for example, hair dryers and microwave ovens may contribute to peak exposures but not to time-weighted average, because they are used for short periods of time.<sup>24</sup> Thus, even if our study could elicit accurate reporting of appliance use, there would be uncertainty regarding the actual exposures experienced by the child and the proper metric.

*Reporting Bias*

Reports about one's own or one's child's typical behavior several years earlier are prone to error, particularly because behavior patterns change rapidly with age. The respondent's report may reflect habits from another year or another child in the family. To the extent the errors are *nondifferential*, affecting cases and controls equally, they tend to reduce the apparent association between exposures and disease<sup>25</sup> and to distort dose-response patterns. In this setting, however, these errors may be differential, thereby possibly exaggerating case-control differences. For example, many mothers may not report accurately the amount of television their children watched before diagnosis if television viewing patterns changed after diagnosis. Thus, differential misclassification may explain some of the effect found for television if mothers focused on exposure at the time of interview rather than during the reference year and cases watched more television after the diagnosis of acute lymphoblastic leukemia as a result of their illness and treatment.

A second mechanism that could lead to differential misclassification is "rumination bias." A mother whose

child has suffered from a life-threatening disease may recall exposures occurring several years earlier as she tries to identify some specific action that led to the illness. Among all the appliances covered in the interview, electric blankets may be the most prone to rumination bias, because they have been most frequently cited by the media as having high magnetic fields. Although we did find evidence of inconsistency in mothers' reports of use of electric blankets between the first and second interviews, it was similar for cases and controls (Table 3). We were unable to evaluate the consistency in responses for children's use of electric blankets, because the two questionnaires referred to different time periods; however, even moderate differential misclassification with a low prevalence of use by children (7.1% of cases and 3.0% of controls) could result in substantially biased estimates of effect. We did not find any increased risks for the appliances that were included as "red herrings" (ceiling fans, night lights, and stereo systems), which might argue against differential misclassification as a major factor.

#### Selection Bias

The use of random digit dialing to select controls may have resulted in the selection of fewer children from families with closely spaced births, which may partially explain the higher socioeconomic status of the control families in our study.<sup>26</sup> Factors associated with the participation of controls may also have created some bias in our findings. We compared occupation, education, and income levels of 97 parents of controls who participated in the initial CCG interview but refused to participate subsequently (N = 83) or could not be located (N = 14) with those of the 699 controls who did complete the second interview. The nonparticipants tended to be characterized by low socioeconomic status (for example, 26% reported incomes of less than \$20,000 compared with 13% of participating controls). A similar pattern was seen for educational level and type of occupation of the parents.

Socioeconomic status was inversely related to the use of many appliances in our data (for example, 23% of mothers with a high school education or less reported that their children watched more than 6 hours of television per day, in contrast to 8% of mothers who completed at least 4 years of college). Television viewing was also strongly inversely related to income level. Although adjustment for socioeconomic and life-style differences between cases and controls did not affect the results, it seems likely that control for socioeconomic status was not complete and may have contributed to the elevated risks for some appliances.

#### Random Variation

When a battery of factors is used to assess a single hypothesis, as in our study, individual elements cannot be looked at in isolation. Random variation makes the likelihood of a positive finding for at least one element of the battery greater than for a single factor.

#### Life-Style/Confounding/Time Trends

We have focused on the risk associated with appliances because of their emissions of magnetic fields. Other explanations of a hypothetical causal relation between an individual appliance and risk may be equally or even more credible than magnetic fields. Families in which children watch many hours of television per day may differ behaviorally and in other ways from families in which little television is watched. For example, time spent watching television was reported to be a strong predictor of obesity during adolescence in the National Health Examination Survey.<sup>27</sup> Likewise, characteristics of families in which the mother sews during pregnancy may suggest life-style factors related to a reduced risk of acute lymphoblastic leukemia.

If there were a causal connection between watching television and acute lymphoblastic leukemia, the widespread increase in television viewing around the world from the 1950s through the present time should have caused a large increase in the incidence of childhood leukemia in developed countries. The proportion of U.S. households with television sets increased from 9% in 1950 to 95% in 1970<sup>28</sup>; however, childhood leukemia rates have not increased dramatically during the last five decades, nor are leukemia rates increasing in all developed countries with increasing use of television.<sup>29,30</sup>

#### Conclusion

Drawing a clear conclusion is hindered by the possibility that responses of case mothers may reflect changed behavior in children after diagnosis of acute lymphoblastic leukemia and other sources of differential recall, the potential for selection bias, and numerous inconsistencies in the results. Although not impossible, we think that a causal relation between magnetic fields from the appliances and acute lymphoblastic leukemia is unlikely, particularly in view of the failure to link measured magnetic fields in residences to leukemia in several studies, including our own, and our negative findings on wire codes.<sup>9</sup> We do not wish to dismiss the associations observed for certain electrical appliances out of hand, and accordingly, we are studying whether some aspects of measured magnetic fields associated with television sets, stereo systems with headsets, or other appliances could explain the elevated acute lymphoblastic leukemia risks of the magnitude reported.

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## References

- Wertheimer N, Leeper E. Electrical wiring configurations and childhood cancer. *Am J Epidemiol* 1979;109:273-284.
- Savitz DA, Wachtel H, Barnes FA, John EM, Tvrdik JG. Case-control study of childhood cancer and exposure to 60-Hz magnetic fields. *Am J Epidemiol* 1988;128:21-38.
- London SJ, Thomas DC, Bowman JD, Sobel E, Cheng T-C, Peters JM. Exposure to residential electric and magnetic fields and risk of childhood leukemia. *Am J Epidemiol* 1991;134:923-937.
- Feychting M, Ahlbom A. Magnetic fields and cancer in children residing near Swedish high-voltage power lines. *Am J Epidemiol* 1993;138:467-481.
- Michaelis J, Schuz J, Meinert R, Menger M, Grigat J, Kaatsch P, Kaletsch U, Miesner A, Stamm A, Brinkmann K, Karner H. Childhood leukemia and electromagnetic fields: results of a population-based case-control study in Germany. *Cancer Causes Control* 1997;8:167-174.
- Mader DL, Peralta SB. Residential exposure to 60-Hz magnetic fields from appliances. *Bioelectromagnetics* 1992;13:287-301.
- Kaune WT, Prece AW, Grainger P, Golding J. Assessment of Human Exposure to Magnetic Fields Produced by Domestic Appliances. Report prepared for Lockheed Martin Energy Systems, Oak Ridge, TN, 1996.
- Savitz DA, John EM, Kleckner RC. Magnetic field exposure from electric appliances and childhood cancer. *Am J Epidemiol* 1990;131:763-773.
- Linet MS, Hatch EE, Kleinerman RA, Robison LL, Kaune WT, Friedman DR, Severson RK, Haines CM, Hartsock C, Niwa S, Wacholder S, Tarone RE. Residential magnetic field exposures and childhood acute lymphoblastic leukemia. *N Engl J Med* 1997;337:1-7.
- Kleinerman R, Linet MS, Hatch EE, Wacholder S, Tarone RE, Severson RK, Kaune WT, Friedman DR, Haines CM, Muirhead CR, Boice JD Jr, Robison LL. Magnetic field exposure assessment in a case-control study of childhood leukemia. *Epidemiology* 1997;8:575-583.
- Robison LL, Daigle A. Control selection using random digit dialing for cases of childhood cancer. *Am J Epidemiol* 1984;120:164-166.
- Robison LL, Neglia JP. Epidemiology of down syndrome and childhood acute leukemia. In: McCoy EE, Epstein CJ, eds. *Oncology and Immunology of Down syndrome*. New York: Alan Liss, 1987;19-32.
- Poole C. Invited commentary: evolution of epidemiologic evidence on magnetic fields and childhood cancers. *Am J Epidemiol* 1996;143:129-132.
- Breslow NE, Day NE. *Statistical Methods in Cancer Research. vol. 1. The Analysis of Case-Control Studies*. IARC Scientific Pub. No. 32. Lyon: International Agency for Research on Cancer, 1980.
- Merchant CJ, Renew DC, Swanson J. Exposures to power-frequency magnetic fields in the home. *J Radiol Prot* 1994;14:77-87.
- Wertheimer N, Leeper E. Possible effects of electric blankets and heated water beds on fetal development. *Bioelectromagnetics* 1986;7:13-22.
- Florig HK, Hoburg JF, Morgan MG. Electric field exposure from electric blankets. *IEEE Transactions on Power Delivery*. PWRD-2, No. 2, 1987.
- Delpizzo V. A model to assess personal exposure to ELF magnetic fields from common household sources. *Bioelectromagnetics* 1990;11:139-147.
- Florig HK, Hoburg JF. Power-frequency magnetic fields from electric blankets. *Health Phys* 1990;58:493-502.
- National Institute of Environmental Health Sciences/Department of Energy. Questions and Answers about EMF; Electric and Magnetic Fields Associated with the Use of Electric Power. U.S. Government Document DOE/EE-0040. Washington DC: U.S. Government Printing Office, 1995.
- Gauger JR. Household appliance magnetic field survey. *IEEE Transactions on Power Apparatus and Systems*. PAS-104(9):2436-2444, 1985.
- Stuchly MA, Lecuyer DW, Mann RD. Extremely low frequency electromagnetic emissions from video display terminals and other devices. *Health Phys* 1983;45:713-722.
- Tofani S, D'Amore G. Extremely-low-frequency and very-low-frequency magnetic fields emitted by video display units. *Bioelectromagnetics* 1991;12:35-46.
- Wilson BW, Hansen NH, Davis KC. Magnetic flux density and spectral characteristics of motor-driven personal appliances. *Bioelectromagnetics* 1994;15:439-446.
- Copeland KT, Checkoway H, McMichael AJ, Holbrook RH. Bias due to misclassification in the estimation of relative risk. *Am J Epidemiol* 1977;105:488-495.
- Greenberg ER. Random digit dialing for control selection: a review and caution on its use in studies of childhood cancer. *Am J Epidemiol* 1990;131:1-5.
- Dietz WH, Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescence. *Pediatrics* 1985;75:807-812.
- Andreasen MS. Patterns of family life and television consumption. In: Zillman D, Bryant J, Huston A, eds. *Media, Children, and the Family: Social Scientific, Psychodynamic, and Clinical Perspectives*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1994.
- Linet MS, Devesa SS. Descriptive epidemiology of childhood leukemia. *Br J Cancer* 1991;63:424-429.
- Draper GJ, Kroll ME, Stiller CA. Childhood cancer. In: Doll R, Fraumeni JF, Muir CS, eds. *Trends in Cancer Incidence and Mortality*. Plainview, NY: Cold Spring Harbor Laboratory Press, 1994.

## Appendix

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